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Good day and welcome to the Bank of America Securities and Analog Devices. Today's call is being recorded. I'd now like to turn the call over to Mr. Vivek Arya, U.S. Semiconductor Research. Please go ahead, sir.

**Vivek Arya:** Thank you. Hello everyone, delighted to have you join us this morning or afternoon your time. Especially honored and delighted to have Dr. Greg Henderson, Sr. Vice President of Analog Devices: Automotive, Communications, Aerospace and Defense Division along with Mike Lucarelli, Head of Investor Relations.

The purpose of the call is to really dig into Analog Devices' communications -- especially the 5G product business. And the measure of success of this call is the next time you think of 5G end-radios, you have to be thinking of Analog Devices.

Just a quick intro to Dr. Greg Henderson -- basically the creator of ADI strategy in RF and microwave products, and he has spent about the last two decades in several leadership positions, not just at Analog Devices, but before that at Hittite, at Triquint, at IBM, and MACOM. He holds a BS in Electrical Engineering from Texas Tech and was awarded a PhD in Electrical Engineering from Georgia Tech, and is an author of several patents and technical articles. So I think we are really in for a special treat on 5G.

Now the format will be as follows. Greg will go through some slides that are linked to the invitation email that we sent out earlier this morning, and they are also on ADI's IR Web page. Please contact anyone from our team or from our Sales if you're unable to get or look at those slides. But there are slides that we will start with.

And before we get to the fun stuff, one special request, again, for your support in the ongoing II poll; very important for us internally and your support is greatly valued. So thanks in advance.

With that, a very warm welcome to Greg and Mike and let me turn it over to them for initial comments and then the presentation. Over to you, Mike.

**Mike Lucarelli:** Thanks Vivek; appreciate that. I'll echo what Vivek said. It's a pleasure to have Greg on this call here today. There is a presentation associated with this. It's a short 5-page presentation and it'll last about ten minutes. You can get it from Bank of America, as Vivek said, or you can go to [Investor.Analog.com](http://Investor.Analog.com). If you go to the Events section, scroll down halfway on the page, Upcoming Events, there's a link right there also to that presentation. I'll give you like five seconds to find that if you haven't found it yet. And while you're doing that, I'll read the forward-looking statements in a very brief format.

We'll make forward-looking statements on this call today. We have no obligation to update those statements. And the disclosure is on the first page of the presentation we're about to show.

So with that, I'll pass it over to Dr. Henderson. Thanks.

**Dr. Greg Henderson:** Great, thank you Mike and Vivek, and thank you all for joining us today. I'm here today to talk about our communications business at Analog Devices and specifically focus on our position in 5G. So I have a couple of slides as Mike said. I'll just kind of walk through them. I'm going to start here with **Slide 1** and talk about a breakdown of our Communications Business.

So in 2019, the Communications Business at Analog Devices was about \$1.3 billion. And the way to think of our

communications business is about two-thirds of that business is in wireless and that's all in wireless infrastructure. So we don't put any consumer or handset WiFi-type things in there; we don't really participate in those markets. That two-thirds in wireless is all in the infrastructure side of the market.

The majority of the cellular infrastructure -- macro base station, small cell -- but we also have positions in point-to-point satellite communications and others. The other third of the business is in wireline, and that's in the telecom, networking, and data center business.

Breaking down a little bit further, in the wireless business, our position is that we are the market share leader in radio signal chains for wireless infrastructure. So we have really defined the architecture as we have been participating in this market for a long time, and we are the market share leader.

We have a unique strength in RF and microwave signal chains, mmWave solutions, and power. And with that, we are able to really define the architectures and provide innovative solutions with best-in-class performance, power, size, and cost.

Our software-defined transceiver architecture that we're going to talk about more has really enabled the 5G market that we're talking about today. We are on our fifth generation of that solution that has become the de-facto standard architecture in this marketplace. And we have a very strong design position across the markets. So we have a strong and diversified customer base. It's obviously a relatively small customer base in wireless compared to some of our markets like industrial, but we have a very diversified position across that customer base or across the customers and regionally.

Just touching on the wireline business, in the case of the wireline business, our position is really on precision, control, and power. So we're really focused on the control and power for the wireline optical networks. That's basically our position in wireline.

Shifting to wireless and 5G -- what we're going to talk about today -- we believe that we're well-positioned in this market and that Analog Devices is well-positioned for growth and that the market is well-positioned for growth.

The real macro growth driver for this business is the insatiable demand for broadband connectivity. And I think if you look at these, we try to look at big picture megatrends and make sure that we're investing in the areas that are going to have long-term sustainable growth. And this insatiable demand for broadband connectivity is probably one of the most sustainable megatrends in our business because, really, if you look all the way back to the dawn of the internet in the 90s, there has been this kind of steady exponential growth in broadband connectivity. Sometimes it goes a little faster, sometimes it goes a little slower, but broadly, there's this exponential increase and it hasn't slowed down yet.

And as a matter of fact, the current environment that we're in with these pivots on work from anywhere -- people are doing multi-party zoom meetings as opposed to customer events, this is a call as opposed to it might be normally a roadshow -- it's really putting more pressure on the network and the digitalization is driving this.

So that's the mega growth driver and that is driving both the wireline business and wireless business. And that is definitely driving 5G which is the second growth driver. The global rollout of 5G is just starting. We like to say that we're really in the early innings of 5G, and so we are well-positioned in 5G with a very strong share position. Our architectures have actually, enabled 5G; I'll talk about that more. And so as 5G starts to roll out, we are well-positioned for growth.

This is also driving our wireline business where we participate in 100G/400G carrier networks both long-haul and datacenter carrier networks. And the technologies we have -- RF and Microwave, mmWave and Power -- are providing revenue synergy for us which are expanding our SAM. So I'll talk more about that in a minute.

So now I'm going to pivot even more closely on going to **Slide 2** and talk specifically about what is 5G and how ADI plays in 5G. And I have this kind of cartoon picture on Slide 2 of a 4G network. And the important thing to understand is that Analog Devices is in the radio head. We do the radio signal chain. So the part that is up the mast and down at the bottom of the pole, that's basically where the Analog Devices' content is. We provide that radio signal chain.

In the case of a 4G network, typically those base stations have a number of antennas and they cover a sector with a certain amount of spectrum. And a typical 4G base station has anywhere from a single antenna to two antennas to four antennas, so maybe the average number of antennas in a 4G network is about two antennas. And those two antennas cover that sector and all of the users that are in the sector share that bandwidth in that spectrum. And so that's effectively the technology for 4G; it's a very efficient use of that spectrum, but they share that spectrum.

Moving down to **Slide 3** -- which shows you what happens in 5G -- and in the case of 5G, effectively you're able to reuse that spectrum in space with a technology that's called Massive MIMO. And there's two technologies in 5G -- Massive MIMO and mmWave -- but the driver for the volume of 5G, at least in the next few years, is going to be Massive MIMO. And by significantly increasing the number of antennas -- so a typical 5G Massive MIMO system has 16, 32 or 64 antennas -- you can actually, effectively reuse that spectrum in space, and you can steer beams to different users.

And effectively on average, you get five times more the capacity inside that same amount of spectrum. And they call that spectral efficiency, so that's about five times more spectral efficiency. This is a huge advantage to the carrier. So now the spectrum that they paid so much money for that they have to build towers for, they can get 5x capacity on the same spectrum. That's huge.

The tradeoff is that you have a more complex base station with a lot more channels. And it turns out that on average, there's about eight times as many channels per base station. And the beauty of this is that Analog Devices participates right in the signal chain that gets multiplied by eight. So we do that radio signal chain from the digital to the antenna. We're in the part of the content that's multiplied.

Now obviously as we go to 5G, we have provided integrated solutions that provide a cost-per-channel benefit to our customer because otherwise, it's just not practical to deploy 5G. So it's not like we get 8x dollars per channel; we've innovated on the system architecture to give a benefit in cost per channel to our customer. But there still is a dollar increase due to the channels, as well we're adding power and other signal chain that will show up in our content opportunity. So we estimate for Analog Devices it's about a 4x content opportunity increase when you're looking at 5G versus 4G. And that's a big part of our growth driver.

So moving on to **Slide 4**, okay, what's inside that base station? And this is basically what's inside a 5G base station. It's a significantly simplified architecture. And the reason for that, if you go back to 3G or 4G base station that we have discussed previously during our investor days, there's a lot of chips and a lot of complexity inside that. We have really simplified and our customers have simplified. This is effectively what's inside the base station.

You start at the left-hand side. You have this thing called a beamformer. That's this complex digital logic that steers the beam among the antennas. Then goes from the beamformer to the digital frontend. And effectively, the majority of the rest of that signal chain from the digital frontend to the antenna elements is a solution from Analog Devices. We've talked many times about our software-defined transceiver; that's the box in the middle. That integrates the complete radio signal chain. The latest generation solution that's in production for 5G is a four-channel solution, four-transmit channel, four-receive channel, four-observation path for linearization.

And that architecture has enabled 5G. We defined that architecture many years ago back in the 2G/3G ecosystem times. It took a while for the market to accept it, but it has now become the de-facto standard.

So the transceiver is the core, but we've also been able to add more content. We've added that integrated receiver frontend. That's technology that came from Hittite through the acquisition. So we also have a very strong share position in receiver frontend. And further, we're integrating in now, power management for this whole solution from LTC. So we're able to expand our SAM beyond the transceiver, and this is the synergy through our acquisition from Hittite for the receiver and LTC for Power.

The other thing we're doing to expand SAM is our solutions are moving left into the digital frontend. We are adding more and more digital capability -- we're adding algorithms. The solution we sell in production today has the capability for linearizing the power amplifier, and we have customers that buy that solution from us. It's a digital algorithm solution and we get to charge more money per solution by having that. So that's another way in which we are expanding our SAM in the 5G market.

So just to wrap up – I am now on **slide 5** – and talk about 5G and then we're going to open the call to Vivek, for Q&A. There's kind of three things that we want to leave as key messages.

First, from a customer position perspective, we are defining and leading 5G architectures. We have created the software defined transceiver. And more and more, we are co-developing with our customers the radio architectures for 5G.

In addition, we have a very strong and balanced share across the ecosystem. So if you look back to our position in 4G, we definitely had position where we were stronger with some customers than other customers, we have a very strong share in 5G across the ecosystem and so that's a show of the strength of our solutions and our position.

From a content perspective, the thing I want to make the point of is that 5G has a higher content for ADI. We are in the part of the signal chain that multiplies for 5G so that multiplication gives us a content increase. And in addition, we're expanding our SAM. We are expanding through the technologies we've added from Hittite and Linear, and by expanding into the digital through software and algorithms.

And finally as a growth driver from a deployment perspective, I think it's important to understand that we're in the early stage of a multi-year 5G rollout. 5G over the next year or two is going to be driven by China just like 4G was heavily driven by China. But 5G is a global standard and it will be a global rollout. And all the regions in the world will eventually roll through 5G just like they did with 4G. So we expect this to be a multi-year growth driver.

So with that, I think we'll close and hand it back over to Vivek.

**Vivek Arya:** Excellent. Thank you so much, Greg.

Maybe what I'll do is start with a very basic question. What is so special about a software-defined transceiver because that seems to be one of the goals or DNA and the expertise that ADI brings to the market. So what is the software-defined part of a transceiver? Why is it important? You know, what are the competitive kind of barriers to entry, and why is this so important when it comes to deploying a 5G network?

**Dr. Greg Henderson:** Yes, thanks Vivek. So maybe I'll start by giving just a little bit of perspective. If you roll back - you know, Analog Devices has participated in this market for a long time. And our original heritage was kind of our high speed converter portfolios. So if you roll back, you know, back in the 3G days, a 3G base station were the days where we were just starting to get to integration. So we would sell high-speed converters, we would sell RF amplifiers. 3G was when we just started to get to some levels of integration where we would be integrating some of those component level solutions into a base station.

And at that time, we started out with, I would call them, semi-custom integrations where we would integrate solutions for individual customers. And so that's maybe about five years ago. And so we participated in the 3G

buildout and actually even in the 4G buildout with this kind of architecture.

But one of the challenges was that it was a solution that didn't scale. Every customer had a different architecture, a different frequency band. We ended up doing semi-custom solutions for effectively each customer. And we didn't get any leverage out of the platform.

And so we realized that this was long-term not really a scaleable solution and so it was over five years ago that we came up with this concept of a software-defined transceiver. And basically, it's a flexible direct conversion receiver that you program for the individual architectures and use cases. And it actually, took the market awhile to accept because there are some tradeoffs and also, you know, new technologies are sometimes disruptive; it takes awhile for the market to accept it. So it took awhile. And actually, in the 3G ramps and even in the early days of the 4G ramps even though we had the technology, it wasn't really accepted.

But I would say it was in kind of that densification stage of 4G that we started to get strong customer acceptance, and that's also when small cells deployed and it was a very good architecture for small cell because, again, it's software defined. You can reuse the solution for both macro and small cell.

And we also innovated to improve the performance, to make it more flexible, to cover wider bandwidth, so we were innovating over that time. So it was in the 4G densification when we really got a strong acceptance of the architecture. And what that did is it integrated a lot of discrete components on the board into a single chip. And it also made it very, very flexible so that single chip could be used for a bunch of different use cases.

Well it turns out that when you go to 5G Massive MIMO and you try to fit 64 channels in a base station, it's basically not practical to use the old architecture anymore. So we had proven that the architecture worked in 4G and it was really the only practical architecture for 5G. And so because of that it became the de-facto architecture to enable 5G. And I think we feel -- at Analog Devices -- proud of the fact that our architecture, in many ways, has enabled 5G to happen.

So what is unique about it is that it's a flexible architecture where you use the software to program the use case and control the part and it gives you much more flexibility and a much higher level of integration in terms of the number of channels you can get on a single piece of silicon.

**Vivek Arya:** Got it. And the flexibility aspect, Greg, of this, is that to do with, you know, the kinds of diversity of the use cases that one would see in 5G, does it have to do with, you know, the different times of the day and the different amounts of traffic? Like what is the need for this additional flexibility in 5G?

**Dr. Greg Henderson:** Yes to that's a good point. The flexibility is really about how you design the radio. So it's about the flexibility of the use cases. And you've made that point. I mean I think with all domains that you get into, there's actually, a lot of complexity to our customers about building base stations. And it turns out the stuff all works to magic, but, you know, when you buy a typical cell phone, for example, that cell phone operates over, I don't know, tens of frequency bands. And all those bands have to interoperate with each other. So there's all these different use cases when you roam from one network to another and you're global and you're in a remote country and you're on their 3G network, so you have to support all of these different frequency bands.

And the infrastructure companies have to build infrastructure for everyone of those bands. And the interference environment where different bands interfere with each other so its very complicated. And so it's those - the radio design use cases that are greatly simplified by the software design.

There's other things about the architecture that probably don't have time to get into, but there are other things we have done in the architecture that simplifies the overall radio design for the customer. So one of the other big challenges in the radio is the filtering you do right by the antenna because you have to filter out to block other jammers and stuff like that.

The architecture that we have through the software defined and through being the direct-conversion architecture greatly simplifies that filtering requirement and for our customers, how many different combinations of filters they need. So that's some of the simplification that's kind of a secondary effect but it turns out to have a big value proposition in the solution.

**Vivek Arya:** Got it. The second aspect that I find interesting in this market is, you know, just the use of the much higher frequency spectrum in 5G. So talk to us about what that does in terms of complexity because I am reminded of the heritage, right of some of the technology here from Hittite who was used to working in higher frequencies. And now it so happens that 5G is also happening in some of these higher frequencies.

So talk to us about, you know, what 5G means in terms of the spectrum requirements and how that influences the complexity of this solution?

**Dr. Greg Henderson:** Yes. So I think, you know, the important thing to understand with 5G is there are two different kind of major solutions in 5G. There's Massive MIMO -- which operates in the Sub-6 GHz band, and then there's mmWave which operates typically 24 to 38 GHz or something like that.

First, just starting with Massive MIMO, the Sub-6 GHz. We believe that Massive MIMO is going to drive the majority of the volume for 5G over the next few years and then it will transition to millimeter wave later. There's millimeter wave out there and we're participating - I'll get to that in a minute. But we believe in Sub-6 GHz, the real key about 5G is that in general, 5G is being deployed in new spectrum. There are some people that are re-farming old spectrum, but in general, its new spectrum.

And for 5G to work well, you want wide bandwidth as well as it to have the Massive MIMO, et cetera. So even in the Sub-6 GHz case, it tends to be new spectrum and the new spectrum tends to be higher frequency than the old spectrum. So 3-1/2 GHz for example is being deployed in China. They talk about deploying 2-1/2 GHz in North America. There's a C-band auction coming up in North America that's in that 3 or 4 GHz range. So this is still a higher frequency and there's more challenges on propagation, et cetera, from the frequency perspective.

And from a financial perspective, higher frequency, smaller coverage footprint. So at 3-1/2, the coverage footprint is less than 2-1/2 which is less than 900 MHz. So that means there's more base stations. So that's kind of a fundamental of the physics. And so in Sub-6 GHz, it's a higher frequency.

And then when you move to millimeter wave, the advantage of millimeter wave is you can get very high bandwidth, you know, tens of GHz or something like that. But it also tends to be an even smaller footprint because it tends to have a smaller footprint. The millimeter wave technology is very different. We are participating heavily in millimeter wave and Hittite had a strong millimeter wave portfolio so we are in the solutions that are out there. The market is emerging.

But our view is that the Sub-6 GHz is going to deploy broadly. It's basically going to fill up capacity on Sub-6 GHz, and the millimeter wave is like a small cell technology; it comes in later and it adds capacity as you need. And so it's an important solution but it's going to tend to have a higher volume later in the market cycle.

**Vivek Arya:** Got it. Now one other question, you know, that goes to complexity and that leads into kind of the competition is that, you know, Huawei, I think said in the last year, "Look, I can deploy 5G. I don't really need any components from U.S suppliers." But just given the complexity of the radio, do you think that there is a substitute here? Do you think, you know, whether it's Huawei or whether it's anyone else, do you think somebody can design an alternative to do what you do?

**Dr. Greg Henderson:** Well look, we always have competition and we will always have competition. So we, you know, don't believe it's a competitive free market and so there is competition out there and we're always keeping our eyes out for new competitors that might be showing up and to make sure that we're staying ahead.

But I think from our perspective, the important thing to understand is that, number one, the architectures that are out there today are the ADI architecture. We defined that architecture, we're on our fifth generation. We're investing a lot of our profits we're making in this business right back in R&D because this is an innovation engine-based business. And so we talked about how we're expanding the SAM, how we're adding in the solution from Hittite, how we're optimizing the power, how we're expanding our digital and algorithm capability.

So we feel good about our position. We feel that we have the best solution out there. I think the market has rewarded us so far with our share position and we feel that we are going to continue innovating.

But one thing that I will say is that we, you know, we know that it's a very dynamic market and we need to keep innovating on the next and next generation to stay ahead, and that's our strategy.

**Vivek Arya:** I see. You know, quickly while we are on this topic of Huawei, if you could just update the audience on how much exposure is left to Huawei and, you know, if any of these new restrictions being proposed by the Department of Commerce, will they have any impact on your business in China?

**Dr. Greg Henderson:** Maybe I'll let Mike start first a little bit on the specifics.

**Mike Lucarelli:** Yes, sure. I'll recap what we said at earnings call a couple of weeks ago, Huawei, for us, was a mid-single digit customer until about a year ago when the first restrictions came in May of '19. Since then, they've been cut in half. They are a low-single digit customer over the past 12 months and in our 3Q outlook and our go-forward basis.

There are new rules coming out from the government all the time. So far there's been no direct impact on us -- I would say a very important thing about our position broadly. We have good share everywhere. So if things shift amongst who deploys where, we still benefit. I think that's the one thing that's important to get across, you led off with it Vivek.

If you want to invest in 5G, you have the best exposure with ADI. I'll pass it to Greg for some more details.

**Dr. Greg Henderson:** Yes, I mean I think to Mike's point, Huawei is still a customer of ours and, you know, our general perspective is, you know, we believe in supporting the ecosystem broadly. But also, our design position is broader than it's been ever, I think, from that perspective. And so I think that's the key thing to understand is that we have a broad strategy. We're focusing on the ecosystem and making sure that we do as much as we can to get as much penetration broadly, and right now we have a good position broadly. So we feel, you know, we are navigating the situation like everybody else, but we feel comfortable with our position.

**Vivek Arya:** Got it. Now let's move to, you know, some of the more interesting aspects -- the other interesting aspects which has to do with content growth. And, you know, Greg, you mentioned opportunity for 4x content expansion. And I imagine that, you know, with 5G, you're share probably improves, right, given the complexity?

So given that, you know, you're doing about \$900 million or so in your wireless business as everything converts over to 5G, should we start thinking ADI wireless business will turn towards \$3-4 billion at some point?

**Dr. Greg Henderson:** I don't know if I'm going to give a specific number to what the wireless business is going to trend to.

**Vivek Arya:** Right but basically the question is just content growth and, you know, what drives it. You know, where are we, essentially, in the wrap? I'm not trying to hold you to a specific number. But just, you know, as we think about content growth because these are such big numbers, right, three to four times. You know, what is driving that? You know, how sustainable is that and how much of that - where are we in that cycle?

**Dr. Greg Henderson:** Yes so I think the thing to understand is that we see the transition to 5G happening quickly, right. So I think we see in FY20 we have material revenue in our wireless business driven by 5G, we see the transition to 5G happening quickly. You know and I'm sure your customers know about the regions deploying, right. Korea was the first to deploy, China is deploying largely right now. But this is the early innings of 5G.

So I think the important thing to understand is that we see this as the early innings of 5G. And we believe that the wireless business is a growth business for ADI so we are investing in this business as a growth business. It's going to drive growth over the next few years and we're going to benefit from, the trends of deploying 5G and from our leadership position. And we're confident in our growth position.

**Vivek Arya:** Okay. But Greg, what - maybe just to, you know, kind of push you a little bit on that, what is the right kind of ballpark to think of when we think of your content in 5G because I think as you were describing the deployments, you mentioned the range of, you know, antenna configuration 16, 32, 64. And I think there is some expectation on the 4G, you know, content was somewhere, you know, in that \$80-100 somewhere in that neighborhood.

So should we just take four times that? Like does it change if you are in the 16 and then 32 or 64 configuration? We are basically, right, as investors, we are trying to build some model of addressable opportunity. So what are the important kind of drivers of that model.

**Dr. Greg Henderson:** So, yes. I'll give you a little bit of color and then Mike can maybe give you more specifics on kind of what our guidance is in this. But what I'll say is that when we talk about that 4x content, it's important to understand that that's the opportunity SAM that we have and are creating, right? So some of that we have a very strong position in.

For example in the transceiver today, some of that is the expansion opportunities into power, for example, where we don't have a strong position today but that we're adding that capability as we go over time.

So I think you need to think about that as kind of an overall opportunity for us that we are moving into.

And so the way I look at this and the way I think I'd like you to look at it, and Mike can talk about our specific guidance we're giving is, we're growing because we have a strong share position just even in our core, like that transceiver. And that's expanding into the market. 5G is in the early innings and we have a strong share position across.

So that's the way I want you to think about it. And maybe Mike can talk a little more about the guidance we're giving.

**Mike Lucarelli:** Thanks, Greg. Yes. You're right, Vivek. If you think about it, Greg outlined this in his presentation, the more radios, the more channels you have, the more content we have. So at 16 or 32 is less than 64. What the mix is, we're unsure.

Sixty-four has the most efficiency but it also costs the most. And we have the most content in those systems. What we said is, you're right, the 4x content increase. Say it goes from the 100s to the 1,000s. It's 100 per base station, three of those, three radio heads per base station and you kind of multiply beyond that.

But that's an Excel spreadsheet. And it's not as easy as that Deployments happen at different times across the globe. And also what Greg said is, as deployments happen - and they're just starting today. And if you look at our first quarter revenue in communications, it was 240 million. That's the same level it was at in 2017 before 5G started.

So we're starting from square one and we're starting to see that 5G growth pick up here in the midyear in '20. And



it should accelerate from here as more deployments happen in China and broadly across North America, Japan, Korea, India, Europe, every geo is going to deploy it.

**Dr. Greg Henderson:** The other thing to keep in mind as well, and I'm sure you know this when you tracked it before is that these deployments are a little lumpy, right? So, we get business when our customers get business. And so, quarter-to-quarter, you can have kind of this ride up and down. But the trend is clear.

**Vivek Arya:** Right. Absolutely. So, Greg, what have you seen in terms of the architecture of some of these deployments? I think you mentioned Korea, I think, was kind of earlier to start and now it seems like the deployments are accelerating in China. You know, we have not seen the US and European markets deploy as much.

But from the deployment that you have seen so far, what has been the favored architecture? And do you think that architecture is representative of how 5G is going to be deployed? Like, you know, are these early deployments favoring 32 antenna or a 64 antenna architecture? Give us a flavor for what you are seeing in reality in some of these deployments.

**Dr. Greg Henderson:** Yes. I would say what we're seeing is that the early deployments are, again, I think, you know, we talked about massive MIMO and millimeter wave. The early deployments are volume massive MIMO.

And I would say the primary mix is 32 and 64. And I think the jury is still out. Some carriers are actually even deploying both because they're saying, okay, in some places they're going to do 64 and in some places, because they want a little bit more capacity, some places they're doing 32. So I think we don't actually know the exact mix.

It does seem that the 16 channel is a lower probability So it's somewhere in that range. I think one thing is that the carriers are learning, too, as they do these wide scale deployments, how the networks are actually used. It's about capacity, as Mike said, the math and science is pretty clear, right, in terms of the trade-off between how much a base station costs and how much capacity you're going to get in a sector.

What's not so clear though is that as this capacity is added, how do people use it? And so it's going to be a complicated feedback system that the carriers are going to learn. And that's part of the reason why nobody exactly knows what the right end use case is because it's a little bit of a chicken and egg.

Until you have the bandwidth you don't know how people are going to use it. And then they start to use, they put more demand for the bandwidth so that's going to take a little time between the deployments to kind of settle out.

**Vivek Arya:** Got it. So if you look at them, you know, in terms of the 5G deployment, are you still seeing kind of that three radio head per base station, like what is the configuration? And when we talk of content growth, should we take that content and multiply it by the number of radio heads or how does that kind of math work to get us to the 4x overall content growth opportunity?

**Dr. Greg Henderson:** I think it's a very complex environment. My message is the thing to understand about the 4x is that's the opportunity. You know, the exact complexity of how many radio heads per base station and 32/64 is really an evolving and emerging situation among our carriers and among our customers and their customers.

And so, overall we're confident in the channel counts going forward. But exactly what those numbers are is a little complex.

**Mike Lucarelli:** At a high level, I'll say in general there's three radio heads per base station. If you look at 4G there were three radio heads and 5G, it's similar.

**Vivek Arya:** Got it. So the content growth is at each radio head or is it over the three radio heads combined?

**Mike Lucarelli:** It's the same. There's three in 4G and 5G so you can negate the three and so the 4x content is the increase.

**Vivek Arya:** Got it. Okay. The next thing is, you know, as when the deployment starts shifting to U.S. and Europe, do you see any change in architecture that could create a difference in content? Or do you still see 32 and 64 kind of being the preferred more just massive MIMO deployment?

**Dr. Greg Henderson:** You know, I guess what I would say is that we have no evidence right now to believe that it will be different. But I think you have to understand that it's a trade-off on base station cost, capacity and then user behaviors. And user behaviors are different, right?

In Europe user behaviors are different than they are in Asia, which is different than they are in North America. So I think it's going to probably evolve. But it's clear that there's no reason to believe it's fundamentally different. But the exact mix is, you know, I actually don't know.

But I don't believe our customers really know either. I think they're going to figure this out as they understand the deployments and see what the user behaviors are.

**Mike Lucarelli:** I will say one thing to that. I think it's an important point Vivek that you're making that North America is in the future. And as you see from here forward, you're going to start seeing some massive MIMO deployments on the Sub-6 GHz realm beginning later this year.

And then Greg talked about the C band auction, which opened up more spectrum. You need to have the spectrum first before you can deploy 5G. And that's what's starting to happen later this year and into next year. So we start seeing North America become more part of our mix of 5G through next year and beyond.

**Dr. Greg Henderson:** I think one thing to know is the Sprint-T-Mobile merger has created a carrier who has significant spectrum for massive MIMO 5G in North America. And so that is the first kind of anchor point for this largely. And they've announced that they're going to deploy. And that has also driven the C band auction, which the other carriers will probably participate in.

So to Mike's point, we believe that the next major market after China is North America and the trends are in the right direction that that's going to start to - once that spectrum is out there, you pay a lot for spectrum, you're going to want to deploy it. So that's going to be the next major market to drive.

**Vivek Arya:** All right. One of the headlines I particularly wanted to touch on was there was some kind of litigation back and forth between Analog Devices and Xilinx with their RFSOC product. So without going into the merits and all the litigation, et cetera, I just want to know from a technology perspective, you know, does one solution or the other benefit if there are higher antenna counts?

**Dr. Greg Henderson:** Here's what I'd like to say about that. I think I showed you what the architecture is for a typical 5G base station in my presentation, that kind of block diagram. There is a heavy digital content inside the base station that beam former and then the digital front end.

And as a matter of fact in 5G massive MIMO one of the big complexities is that beamforming is a very complex digital chip. And it actually turns out that, it is one of the highest complexity parts and actually is driving the power consumption. Actually a lot of it is driven by that digital.

One of the transitions in 5G is the power consumption in the base station is driven by digital as much by RF. And that's really a shift from, say, 3G where it was completely the opposite. Power consumption was almost all driven by the RF.

So as the digital drives that power consumption, then the decision point for the customer is they have to choose an optimum partition to give them good power consumption. And what I can say is that the vast majority of the customer base is using an optimized digital ASIC solution or those digital solutions in the base station.

And as well, we are moving to the left of that partition and adding some of that digital into our solution in an optimized way to give an optimum partition for performance and power consumption. And so I would say that's the way to think about the market is that the vast majority of our customers are using custom purposed optimized digital.

**Mike Lucarelli:** The one thing I will add Vivek, is I think we, as a company, have been pretty consistent over the last 12, 18 months. Before litigation, after litigation, we're the market share leader. That hasn't changed. Our message has not changed at all over the past 18 months. And you're seeing that kind of manifest in our revenues now.

**Vivek Arya:** Got it. So basically the point is that configuration is becoming so complex that it is better to optimize the digital and the analog parts separately as opposed to driving huge integration between them, right?

**Dr. Greg Henderson:** It's also about what's the right architecture and what's the right partitioning. So I talked about the digital and how digital needs to be custom. The other thing to understand is that a radio is not a data converter. Like I said when we go back to the 2G, 3G days we sold standalone data converters and a bunch of RF components.

But now we sell an optimized system solution, which is a complete radio signal chain. Our software defined transceiver is a complete radio signal chain optimized for massive MIMO in 5G use cases. And so that is what's also the understanding is that the digital is customized. But also our software defined transceiver is a target architecture for 5G.

**Vivek Arya:** Got it. Greg, how does millimeter wave change your content opportunity? You know, obviously there is less prospects for millimeter wave in that's what we hear from a number of players in the market. Although I think some telecom carriers are very interested and excited about deploying millimeter wave.

What do you see the role of millimeter wave and how does your overall content opportunity change if networks do start, or at least part of the networks do start, adopting millimeter wave.

**Dr. Greg Henderson:** So two things, first. I mean, networks are adopting millimeter wave. It's just a question of how fast that millimeter wave grows and we definitely are part of those solutions now. You know, the thing to understand about millimeter wave is millimeter wave is another multiplier in antenna count.

So millimeter wave solutions might be 256 or 512 antenna. So now it's a completely different architecture. So millimeter wave today tends to be analog beam forming as opposed to digital.

So it's kind of like apples and bananas. But there is a much higher channel count. So there is a lot of content. And that content tends to be kind of RF millimeter wave content because of the way the architecture works. And so there is a very strong content position in millimeter wave because of that as well as the millimeter wave is fundamentally small cell because of the higher frequency.

So to cover an area you need a lot more. So you have more antennas and smaller coverage footprints. So there is a lot of content opportunity in the millimeter wave and it's beyond just that. There's power and other opportunity for us so we see content multipliers in millimeter wave as well and we are participating there.

So we see that as a next wave. We feel like the volume for that comes, like, small cell did to 4G. It's after the massive kind of early deployment so that's the reason why we see it out there. But we're participating in those

designs. We're in those systems. We're working with our customers. And so we believe in millimeter wave just that it's farther out.

**Vivek Arya:** Got it. You know, the one other interesting thing that you mentioned was the incremental opportunity on the base station power side. I would imagine that some of the technology came from LTC. Talk to us about what you are seeing in terms of design wins, you know, the pipeline there. How is the visibility of getting that solution into customers as they deploy 5G?

**Dr. Greg Henderson:** Yes. So I would say that we have our first power designs ramping now for wireless. So we have revenue now that's come with our power design. So we are seeing that opportunity actually come through from a revenue synergy. And in many ways this market, because of the time to revenue in this market, is one of the earlier revenue synergies that we're seeing come through from the LTC acquisition.

I would also say the other thing to understand is that as we are developing our next generation architectures that are not to market yet, but we've been developing, we've been able to co-develop and optimize power solution with the rest of these signal architectures.

So that's when we believe that when those things come to market, which aren't to market yet, we will have an even stronger value proposition because the signal chain and system is optimized to work together. So we're seeing revenue synergies now and that's going to accelerate as these things start to come through.

**Mike Lucarelli:** Yes. I would also remind people on the call that before ADI acquired Linear, Linear did almost no business in the wireless communications market. So this is a greenfield opportunity for Linear. And it's basically going from nothing to something. So it's all additive to Linear's business pre-deal.

**Vivek Arya:** All right. Then the next thing, Greg, you started to mention, and I think, Mike, you also referred to, you know, the way the business is about that \$240 million or so quoted in the last quarter. Completely understandable. This is very lumpy business.

But with 5G starting, shouldn't we have seen better growth? You know, because when I look at that number and compare it to where the business peaked, I think it was 360 million last year. I imagine some part of it was Huawei that came out with all the restrictions.

But at this point, how much of 5G is in this number and how should we just think about the longer term growth? Like, if we had to model ADI's communications segment for the next three to five years, what is the reasonable growth rate range that we should assume?

**Dr. Greg Henderson:** So just to give a little commentary kind of on the dynamics in general and then, again, I'll turn to Mike and he can give specifics on the guidance we're giving. But the important thing to understand is that, you know, the communications market can be lumpy.

And this lumpiness is maybe also aggravated by some of these geopolitical tensions which have customers pull things from left to right in some of the previous events, right? So there's a little bit of lumpiness. So quarter to quarter, it's a little challenging to get away from lumpiness.

I think we talked about this before though. Our 2019 performance was largely about share gains in 4G. And so we saw that growth and we saw those share gains. And also if you look at the way these markets go from a lumpiness perspective if you look back through 3G or 4G, you go through the early ramp and then you go through kind of sustained growth, densification, slight malaise and then the next G goes.

And so we kind of have been going through that transition of slight malaise because as the 5G starts to happen, people don't really want to spend on 4G unless they have to. So I think there is a lumpiness and there's a little bit

of a timing to how these trajectories go.

But our view is strong position in 5G, good share, early days. So we're in the early growth phase of 5G. And for that reason we believe it's early innings for kind of sustained growth. And for that, I'll hand it to Mike and see what he's willing to say.

**Mike Lucarelli:** If you look at 4G, 4G the trend line was probably 5% or 6% CAGR. Given what Greg said about better share, better content, the growth should be above that going forward. That's how we're positioned.

ADI as a company we kind of target between 5% and 10% long-term growth as a company. And there's no reason to think comms should not be at the high end of that and maybe some years is above that 10%, but it's over the long period.

And I'll go back to, if 4G could do 5% or 6%, we'll grow above that over the long-term driven by 5G as well as the wireline business. Don't forget wireline is also growing. And Greg talked about some of those pieces as well. With this whole work from home, we're benefiting from that also.

**Vivek Arya:** Got it. You know, and then the other kind of near-term question that I just got from another investor was any evidence of any pull-in from Chinese customers over the last one or two quarters that you might have seen that we should keep in mind?

**Dr. Greg Henderson:** We don't believe there are significant pull-ins over the last couple of quarters. But, again, the driver for the market right now is the China deployments.

And so there is a dynamic that these deployments go. The carriers do tenders. They expect their customers to ship very shortly after that so our customers build ahead of the tenders.

And so you will see a lumpiness and an up and down quarter to quarter but we believe that the business that we've gotten over the last few quarters in China is driven by the ramp to the current tenders in China. And we don't see significant pull-ins.

**Vivek Arya:** Got it. And, you know, one other question that I got was back to Huawei. So let's say for whatever reason Huawei is restricted and at some point, I imagine they would run out of components also.

Does that create a pause in 5G deployments in China? Or do you think that Huawei's competitors, right, ZTE or Ericsson or whoever else, that you are kind of widely diversified across them that beyond just some minor procrastination that life will go on, that 5G will still be deployed as aggressively in China even if there are restrictions on one of the suppliers?

**Dr. Greg Henderson:** Well. You know, it's hard to predict what governments are going to do. But what I can say is that the trends to China 5G, you know, China is everything we see and everything we read and hear and you and your investors can read as well.

China is committed to 5G. They want to be first to widescale 5G. And also I believe that they see it as an infrastructure program driving the economy in the current environment that they're in. So everything we believe and everything we see is that China is committed to 5G.

And then secondarily we do have a very strong position. So we are comfortable that we will benefit from the China 5G ramps regardless of exactly how the share is mixed.

**Mike Lucarelli:** You're right. I mean, the number of base stations is what drives our business. If there's less base stations then there's less business for us. But that's one part of the equation if there's less base stations. But the second part of the equation, we have share across all of them.

So if that share pivots to other guys, we're just as well positioned if not better at the other guys internationally. So there's a whole mix of things going on there that's really hard to figure out what the outcome is outside of as 5G deploys, we benefit.

**Dr. Greg Henderson:** The other thing we learned from the 4G is if I remember back in the early days of 4G there was a lot of debating, like, okay, well, there's always debate, you know, would Europe really even deploy 4G or is 3G good enough? And 3G is almost as good as 4G and maybe they don't care.

The lesson is, is that these are global standards and they go global. So I think that's the macro megatrend. I have no question that 5G will go global and that it's going to happen. The month-to-month and the timing of any one country or carrier, yes, it's a little bit uncertain. But there's no question that 5G will go global and no question in my mind that China wants to be at the front of this and not the back.

**Vivek Arya:** All right. Does it matter to ADI if 5G is greenfield deployment versus an upgrade from existing 4G?

**Dr. Greg Henderson:** I guess I would say the vast majority - first order it doesn't really matter to us whether a customer is re-farming spectrum for 5G or whether they are using brand new spectrum because they've got to buy all new radios because radios are all new, right?

So for us it doesn't matter. I would say my understanding is the vast majority of 5G deployments is new spectrum, not re-farming. It may eventually re-farm but the vast majority is new spectrum.

**Vivek Arya:** Got it. And if they have to deploy these advanced antenna configurations, I assume that's kind of new hardware anyway, right, regardless of use cases.

**Dr. Greg Henderson:** Absolutely, yes. Right, you can't - basically for all practical purposes you need new hardware for 5G.

**Vivek Arya:** Got it. Thanks, Greg.

**Dr. Greg Henderson:** So it doesn't really matter.

**Vivek Arya:** And in the last few minutes, you know, we have a number of investors on the call, Greg, who are very sensitive to ESG, environmental social governance, metrics. That's part of their investment process. So I was wondering if you could give us a quick update on what is ADI's position in ESG? How much of a focus is that for your business and for ADI overall?

**Dr. Greg Henderson:** Yes, that's a great question. Actually I think this is a big priority to Analog Devices, our kind of social responsibility. And maybe Mike can make some comments about that broadly in a minute. But just to talk a little bit about how we think about this.

There's many different ways at ADI that we look at our social responsibility. And actually in my businesses in the automotive and communication business, we believe that a significant percentage of our investments are feeding kind of a sustainable future.

So, you know, in automotive most of our investments are about sustainable mobility and the transition to electric vehicles. So we have a significant investment there.

But in the communications space, I think we've seen this especially in the current kind of environment that we're in in this kind of work from anywhere where better communications infrastructure has a significant positive impact on the carbon footprint around us.

And so the efforts that we're driving in communications, both in wireless and wireline, have a significant positive

social benefit in sustainability and then also in connectivity. I think the other thing we see about this is that the better connected people are, the better opportunities they have to participate positively in maybe the new economy that we're in now as opposed to the past.

So those are areas that we feel strongly about and that our investments have a positive impact. And maybe with that, I turn to Mike and he can make a more broad comment for you.

**Mike Lucarelli:** I think Greg did a good job of encapsulating for his business. I'll make one last plug. We actually put out a great report called Engineering Good on our Web site. You can find it on our Investor Relations page. It's like a 70 page document all about sustainability and how ADI is working towards that sustainability broadly across the company.

So I encourage everyone to download it, read it. Reach out to myself with questions. It's very imperative here as a company to continue to push harder on the sustainability front.

**Dr. Greg Henderson:** Yes. And I think like Mike said, so there are whole broad aspects. We have an ADI Foundation now which is investing in this as well. So there are corporate level initiatives as well as we look at the businesses and the business impacts and we are more steering to make sure that our investments are aligned with the long-term sustainable future.

**Vivek Arya:** Excellent. I think with that we are at the end of our extremely informative call. And hopefully if the call is successful, people will always think of ADI when they think of 5G radios.

And we really would like to thank, you know, Greg and Mike for spending some time with us, educating us about the ADI 5G radio portfolio, its differentiators and just how you were thinking about the content opportunity, growth opportunity and rollout and the diversification of the business.

So a big thanks to both of you and a big thanks to all the investors for joining us. And as always, if you have any follow-up questions, please feel free to call or write to me. But with that, let's close the call and thanks again to Greg and Mike.

**[End of segment]**