Development of Solid-State Weather Radar

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Abstract— Today, amid mounting sense of crisis of concentrated heavy rains, weather radars are of growing importance in weather observation and prediction by virtue of their capability of rain-fall measurement over the wide area in a short period of time. Meanwhile, because of the limitation of bandwidth availability with increasing use of radio wave frequency resources, steady demand for weather radar is also expected. Moreover, there is strong demand for decreasing the running cost of weather radar. Toshiba has developed 5GHz and 9GHz solid-state weather radar, complying with the demand the best use of our world-leading microwave transistor technology and radar data processing technology. The radar has attained the specified level of spurious radiation suppression without sacrificing any of radar system performances. Toshiba intends to promote the sales of the solid-state weather radar.

I. INTRODUCTION

Recently, mobile phone is used as personal digital assistance, and the capacity of wireless LAN becomes much larger than before. As a result, demand of frequency resources is growing year after year. There is not enough allocation of new frequency for a part of frequency band, and weather radar is required to reduce band width of radio wave. Also, it is general for weather radar to operate as radar network, and the running cost of weather radars needed to be inexpensive.

For resolving these problems, Toshiba develops 5GHz and 9GHz bands solid-state weather radars by globally advanced technology of semi-conductor and sophisticated signal processing technology. Both radars have high-end function and quality as multi parameter radar, and it is possible to narrow the interval of frequency assignment by one quarter. Solid-state weather radar reduces running cost because expensive consumables that are magnetron and klystron are not used. Moreover, it makes to reduce system stop time by the redundancy of transmitting device. This paper shows about solid-state weather radar developed by Toshiba.

II. SUMMARY OF SOLID STATE WEATHER RADER

A. Specification of Solid State Weather Rader

5GHz and 9GHz bands solid-state weather radars are developed for decrease of running cost and effective use of

frequency resources. Figure 1. and Figure 2. show appearances of 5GHz and 9GHz bands solid-state weather radars. 5GHz bands solid-state weather radar is stationary type. The radar has an observation performance same as klystron radar of peek power 250kw, and the size became less than one half. The transmitter works as not only horizontal polarization radar, but also dual polarization radar including vertical polarization capability. Returned signals from hydrometeors with dual polarization wave are used by identifying hydrometeors such as rain, snow, and hails and improving precipitation observation accuracy.[1]

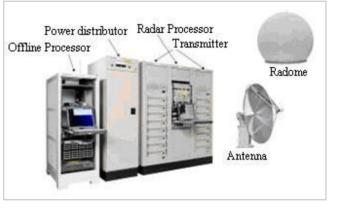


Figure 1. Solid-state weather radar 5GHz band type



Figure 2. Solid-state weather radar 9GHz band type

9GHz bands solid-state weather radar is a mobile type, and the radar has an observation quality same as magnetron radar of max. power 40kw. Instillation space is 2m square, and the weight is less than 2t. Transmitter and receiver are installed near by antenna, and make it reduce loss due to wave-guide. As a result, power consumption is less than 3kVA. Both radars can be LAN access to external device. They can be remotely controlled and transfer observed data by distance. TABLE I. shows typical specification of solid-state weather radars.

TABLE I.	TYPICAL SPECIFICATION OF SOLID-STATE WEATHER RADAR
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Transmitting power	More than 3.5kW (5GHz), 200W (9GHz) (horizontal and vertical each) Less than 20% (5GHz)
Duty Ratio	10% (9GHz)
Minimum receiving power	Less than -110dBm
Antenna gain	More than 42dBi
Beam width	Less than 1.2deg
Pulse width	1 to 350 µ sec (variable) (5GHz)
	1μ sec and 32μ sec (9GHz)
	Reflectivity factor Z(dBz)
	Doppler velocity $V(m/s)$
	Spectrum width W(m/s)
	Differential reflectivity $Z_{DR}(dB)$
	Linear depolarization Ration
Output Data	LDR(dB)
	Differential phase _{DP} (deg)
	Specific differential phase
	K _{DP} (deg/km)
	Correlation coefficient _{HV}
	Rainfall rate R(mm/h)

B. Solid State Transmitter

Conventional weather radar is currently used with electron tube. Even though, peek-transmitting power is highly level, transmitting pulse width is very short term such as one to few microseconds. On the other hand, peek-transmitting power of solid-state weather radar is less than weather radar of electron tube type, but the radar can transmit much longer pulse than conventional radar. Then the radar keeps observation quality better than conventional radar. Transmitting pulse width with expanding degrades range resolution. For solving the problem transmitting wave is modulated by frequency, and processed by the pulse compression after receiving the returned wave. As a result, they succeed to keep range resolution same as conventional radar. Generally, radar cannot receive data while transmitting. When the radar transmits long pulse, the radar cannot observe short distance. Thus, 5GHz band solid-state weather radar is used with short pulse that is not necessary huge transmitting power for short-range observation and long pulse. The solid-state weather radar can observe for long and short distance because of transmitting short and long pulse for each by each.

C. Solid state power amplifier module

One solid-state element dose not have enough power as transmitter of weather radar. Therefore, amplifier is composed with some solid state elements synthesized generally. Figure 3. and Figure 4. show 5GHz band power amplifier module and 9GHz band transmitter/receiver unit developed this time. 5GHz band power amplifier module can produce more than 500w as output power by synthesizing 8 GaAs FET in the last stage. 5GHz band solid-state weather radar accomplish more than 3.5kW over transmitting power in horizontal polarization wave and vertical polarization wave by these 8 modules. In addition, 9GHz band transmitter and receiver unit united LNA (Low Noise Amp) has 200W over output power by synthesizing 4 solid-state elements.

Compared life aspect ,magnetron and klystron need to be replaced every half year to 2 years. Thus ,there is a demerit as stopping the observation during exchange time and running cost will be high. On the other hand, solid-state element has long life period so it makes life period longer compared with electron tube. In addition, in spite of reducing transmitting power due to breakdown some elements, the observation can be kept and that is really effective for system.



Figure 3. 5GHz power amplifier



Figure 4. 9GHz power amplifier and receiver

III. THE PERFORMANCE OF 5GHz BAND SOLID-STATE WEATHER RADAR

A.. Frequency characteristic of transmitting wave

As mentioned in section II, Solid-state weather radar has precise wave form control possible due to high linearity inputoutput characteristic. In general, frequency band increases in width as pulse width gets short. Figure 5. shows a worst case, theoretical transmitting wave form in simulation at $1 \ \mu$ sec pulse width and Figure 6. the real transmitting wave outputted from transmitter.

We can determine that transmitting wave form is close to theoretical concept by control it carefully though distortion compared with theoretical transmitting wave form.

Figure 7. shows transmitting spectrum mixed one to a few μ sec pulse width. As previously mentioned, actually one to a few μ sec short pulse width and from dozens of to a hundred μ sec long pulse width transmit alternately in operation. The spurious level 2.5MHz away from center frequency is 62.17dB lower than center frequency That is to say, it can work out at 2.5MHz away frequency and this is impossible over 10MHz away in the past.

Though the transmitting by only short pulse has its characteristic degrade, we have confirmed that the filter for transmitting has suppress over 60dB.

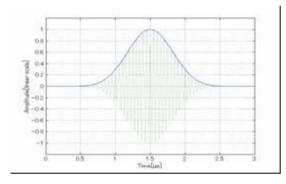


Figure 5. Theoretical transmitting wave form

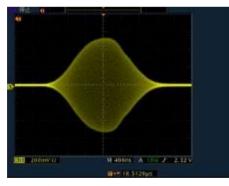


Figure 6. Real transmitter output

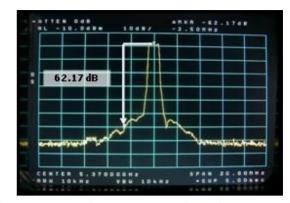


Figure 7. Spectrum of transmission wave (mixture of short pulse and long pulse)

B. Result of precipitation observation

The aim of solid-state weather is radars to observe as original observation as shorten interval of radio frequency assignment. Figure 8. shows a case of distribution of precipitation and Figure 9. shows distribution of Doppler velocity observed by 5GHz band solid-state weather radar.

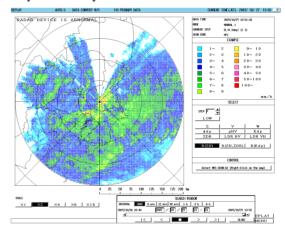


Figure 8. Distribution of precipitation reflectivity

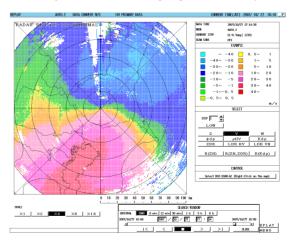


Figure 9. Distribution of Doppler velocity

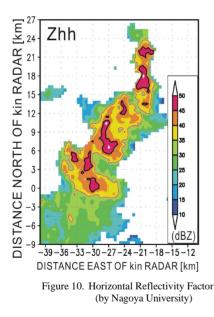
This is relatively strong precipitation, and we can get right distribution of precipitation compared with existing radar's observation. It also gets right continuous change in velocity.

Actually, compared weather radar installed in field with observational result quantitatively, it measured 0.84 with correlation coefficient. In the case of comparing observational data of weather radar, installed at different place, we can see accurate correlation from the viewpoint of the difference of altitude or time. At this point, missing area of the north is due to hiding by mountain and not related the performance of radar.

Figure 10. to Figure 12. show a case of the observation of 9GHz band solid-state weather radar. We can see fine observational result on phase difference between horizontal phase wave, specific differential phase and differential reflectivity.

IV. CONCLUSION

We developed 5GHz band solid-state weather radar and 9GHz band solid-state weather radar by solid-state element. This radar shortens the interval of radio frequency assignment by 1/4 with keeping high-end system and performance as Multi-Parameter radar. Moreover, it has life cycle cost cut-down without changing like electron tube. We will improve more and lead the world for adoption of solid-state weather radar.



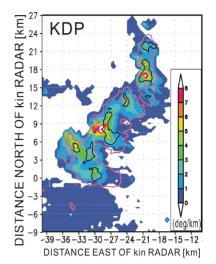
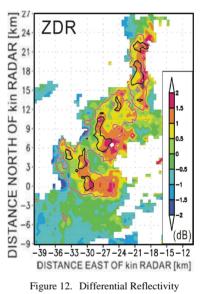


Figure 11. Specified Differential Phase (by Nagoya University)



(by Nagoya University)

ACKNOWLEDGMENTS

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REFERENCES

[1] V.N.Bringi, et al. "POLARIMETRIC DOPPLER WEATHER RADAR". CAMBRIDGE UNIVERSITY PRESS.