DEVELOPMENT 0F MICROWAVE HIGH POWER SOLID STATE PULSE TRANSMITTER

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ABSTRACT

This paper introduces the development of an S-band miniaturized solid-state pulse transmitter. Four-way power combination technique is applied to raise output power. The output power of the RF pulse exceeds 500W, and the combined efficiency amounts to 90%. The transmitter has many other good characteristics, such as small dimensions, light weight, low power consumption, high duty factor and so on. Development of this transmitter will greatly improve the ability of telemetry. It will undoubtedly promote the application and development of pulse telemetry system.

KEYWORDS

Microwave, Solid-state, Pulse, Transmitter, Power combination

INTRODUCTION

The volume and weight of telemetry transmitter will be strictly required in the future. Transmitter will transmit more and more data, so it is very important to develop a kind of pulse telemetry transmitter whose characteristics should be smaller volume, lighter weight, lower power consumption and higher power. In recent years, the development of microwave pulse power transistor improved very fast. It advanced at a miraculous pace not only in high power but also in frequency. The development of high power transistor opens a new technique route for microwave pulse telemetry transmitter.

The advantage of solid state pulse transmitter is obvious. The output power of single amplifier becomes more and more high, which makes it possible to apply the solid state pulse transmitter in vehicle. It is developing tendency of the pulse transmitter.

ENFORCEMENT SCHEME

According to the overall requirement of telemetry system, the output power of the pulse transmitter should be higher than 300W, so power combination technique is often used in transmitter. There are two methods to combine power. One is to parallel many transistors, the other is to parallel many amplifiers. If transistors are paralleled, non-balancing current will pass though the collector and the transistor will be easily destroyed when the characteristics of the paralleling transistors are unbalanced. In the second method, driving power will be distribute to every paralleling amplifier, the output power of paralleling amplifiers will be combined to output. There are many advantages in the second method. As long as the amplifiers are adjusted in good state, high pulse power can be achieved through connection to the mixed coupler. Amplifiers in the second method rarely effect each other. Four-route power combiner is used in this transmitter. The transmitter theory diagram is displayed as figure 1.

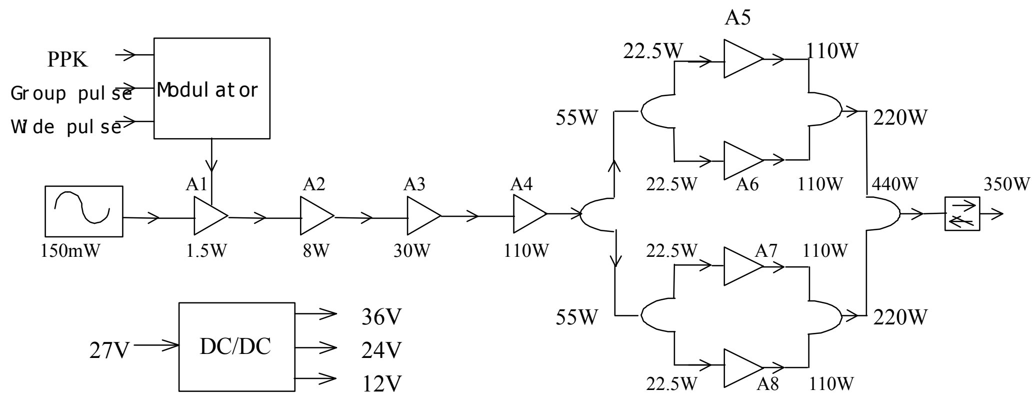

Figure 1. The theory diagram of transmitter

After the power supply runs, the oscillator of the transmitter begin to oscillate. The oscillation frequency is S band and oscillation power is 150-200 mW. When PPK (pulse position keying) signals come, multi-function modulator generates pulse that controls the switching amplifier (A1). The width of pulse is 0.5μs, and the amplitude of the pulse is 24V. The switching amplifier cuts the continue wave into RF pulse whose width is 0.5μs. The output power of the switching amplifier is 1.5W. Then, the RF pulses pass through multistage power amplifiers, power divider and power combiner. The final output power is more than 300W. When the group pulse signal comes, the transmission progress is the same as transmission progress of PPK signal. But in this transmission progress, the multi-function modulator will cut off the transmission of PPK signal automatically. After the group pulse signals are sent out, the multi-function modulator returns to transmission of PPK signals. When wide pulses come, the multi-function modulator does not change their width again but amplify the pulse amplitude to fit the requirement of A1. It is said that the width of the RF pulse is the same as that of the wide pulse. Of course, the multi-function modulator will cut off the transmission of PPK signal automatically. The multi-function modulator returns to transmission of PPK signals after a certain time.

From these transmission progresses, it is certain that this transmission can transmit many kinds of signal. But it can only transmit a kind of telemetry signal at a special time. The PPK signals can not be transmitted when group pulse signals or wide pulses are transmitting. That is say, there is a frame of PPK signals that almost not effect the PPK data can not be transmitted when group pulse signals or wide pulses are transmitting.

COMPONENT DEVELOPMENT

There are pulse power amplifiers, power divider, power combiner, multi-function modulator, oscillator, isolator and power supply in this transmitter. Some key components of the transmitter will be introduced in this paper.

DEVELOPMENT OF MICROWAVE PULSE POWER AMPLIFIER

Generally, about designing microwave pulse power amplifier, it is be considered that the output power, collector efficiency, power gain, band width and the stability of the circuit. Of course, it is impossible to consider all of them. Whether they will be considered or not should be decided according the actual situation. High pulse power is the most important in this transmitter, so the output power will be mainly considered in the progress of design.

In order to achieve high output power, the matching circuit is the key technique. On the allowable condition of the transistor, it is a method to add the input power. But, the input power con not be too high, or the collector efficiency will be decreased and the reliability will be dropped.

There are two methods to design the input and output matching circuits----conjugation matching and large signal S parameter. Conjugation matching is adopted in this transmitter. It can be proved that any complex impedance can be transferred into a pure resistance as long as the proper 1/8 wave transformer is chosen. In order to explain these, figure 2 is displayed.

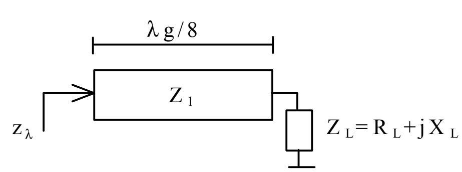

Figure 2. 1/8 wave transformer

If the characteristic impedance of the 1/8 wave transformer is Z1, the load impedance of terminal is ZL.

$$Z_L = R_L + jX_L = \left|Z_L\right|(\cos q_L + j\sin q_L)$$

However the input impedance is Zλ,

$$Z_l = Z_1\frac{Z_L + jZ_1 tgbl}{Z_1 + jZ_L tgbl}$$

$$= Z_1\frac{\left|Z_L\right|(\cos q_L + j\sin q_L) + jZ_1 tg\frac{p}{4}}{Z_1 + j\left|Z_L\right|(\cos q_L + j\sin q_L) tg\frac{p}{4}}$$

$$= Z_1\frac{\frac{\left|Z_L\right|}{Z_1}\cos q_L + j(\frac{\left|Z_L\right|}{Z_1}\sin q_L + 1)}{(1 - \frac{\left|Z_L\right|}{Z_1}\sin q_L) + j\frac{\left|Z_L\right|}{Z_1}\cos q_L}$$

If $$Z_1 = \left|Z_L\right| = \sqrt{R_L^{\ 2} + X_L^{\ 2}} \qquad (1)$$

Then $$Z_l = Z_1\frac{\cos q_L + j(\sin q_L + 1)}{(1 - \sin q_L) + j\cos q_L})$$

And then

$$Z_l = Z_1\frac{\cos q_L}{1 - \sin q_L} = \left|Z_L\right|\frac{\cos q_L}{1 - \sin q_L} = \frac{R_L}{1 - \frac{X_L}{\left|Z_L\right|}}$$

Obviously, Zλ is a pure resistance. The result prove that 1/8 wave transformer really can transfer any complex impedance into a pure resistance as long as the formula (1) is satisfied. It can also be proved that the modulus of the reflection factor of 1/8 wave transformer load terminal is the minimum.

Because

$$\Gamma_L = \frac{Z_L - Z_1}{Z_L + Z_1} = \frac{(R_L - Z_1) + jX_L}{(R_L + Z_1) - jX_L}$$

$$\left|\Gamma_L\right|^2 = \frac{(R_L - Z_1)^2 + X_L^2}{(R_L + Z_1)^2 + X_L^2}$$

$$= \frac{\left|Z_L\right|^2 - 2R_L Z_1 + Z_1^{\ 2}}{\left|Z_L\right|^2 + 2R_L Z_1 + Z_1^{\ 2}}$$

In order to get the extreme value of above formula,

$$\frac{d\left|\Gamma_L\right|^2}{dZ_1} = 0, \text{ Then } Z_1 = \left|Z_L\right|$$

It can be proved that the extreme is actually the minimum. So it can be avoided that large standing wave ratio arise in the whole matching system, which is very important for the transmitter.

1/8 wave transformer can only transfer complex impedance into a pure resistance, but the pure resistance is not equal to the internal resistance of signal source or the load resistance. So1/4 wave transformer is used to transfer the pure resistance into the internal resistance of signal source or the load resistance. These are displayed in figure 3.

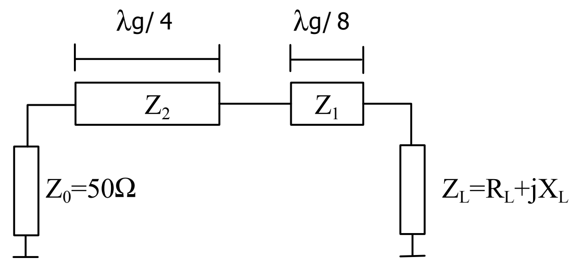

Figure 3. 1/8 wave transformer and 1/4 wave transformer

In the figure 3,if $Z_1 = |Z_L|$,

Then the characteristic impedance of the 1/4 wave transformer is Z_2,

$$Z_2 = \sqrt{Z_0 \cdot \frac{R_L}{1 - \frac{X_L}{|Z_L|}}}$$

After studying the method of matching network, pulse power amplifier can be designed. There are 1.5W, 8W, 30W and 110W pulse power amplifiers in the transmitter.

DEVELOPMENT OF POWER COMBINER

According the network theory, its counter progress can be applied if power divider satisfies the reciprocal theory. That is saying, power divider can be used as power combiner. If many power combiners are connected together, they will form multistage power combination array. Two-stage power combination array is displayed in figure 4.

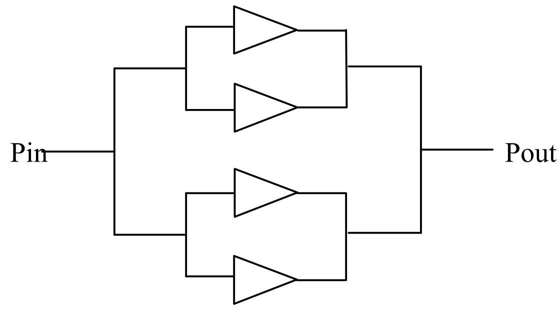

Figure 4. Two-stage power combination array

In order to achieve high combination efficiency, it is very necessary to decrease the insertion loss on the condition of the same performance of amplifiers. So low loss substrate should be adopted, and the standing wave factor of input and output should be decreased. Generally, the loss of n-stage power combiner array is 2n times as that of single power combiner. If the loss of single power combiner is 0.5 dB, the loss of two-stage power combination array will be 1 dB. So the loss should be decreased as possible in high power combination system.

There are 2^n amplifiers in n-stage combination array. If K amplifiers can not work, the output power of combination array is

$$P_{of}=(1-k/2^n)^2 * P_0$$

Where P_0 is regular input power

If one amplifier can not work in two-stage combination array, the output power is

$$P_{of}=(1-1/2^2)^2 * P_0=9/16P_0$$

If two amplifiers can not work in two-stage combination array, the output power is

$$P_{of}=(1-2/2^2)^2 * P_0=1/4P_0$$

Four-route power combiner is used in this transmitter. If one amplifier can not work, the test result is basically same as the value on theory.

CONCLUSION

Four-route power combiner is used in this transmitter. 139W is the output power of every amplifier that has the same performance, and combination can reach 90%. The power of the output pulse reaches 500W. The structure of the transmitter is modular structure. Double-sided installation is adopted in the transmitter, which made full use of the space.

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