

MODE A AND MODE C

THE STRAIGHT SCOOP ON HOW IT WORKS

by

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What happens when you dial "1200" into your transponder? How is aircraft altitude transmitted to the controller? What is Mode A and Mode C anyway?

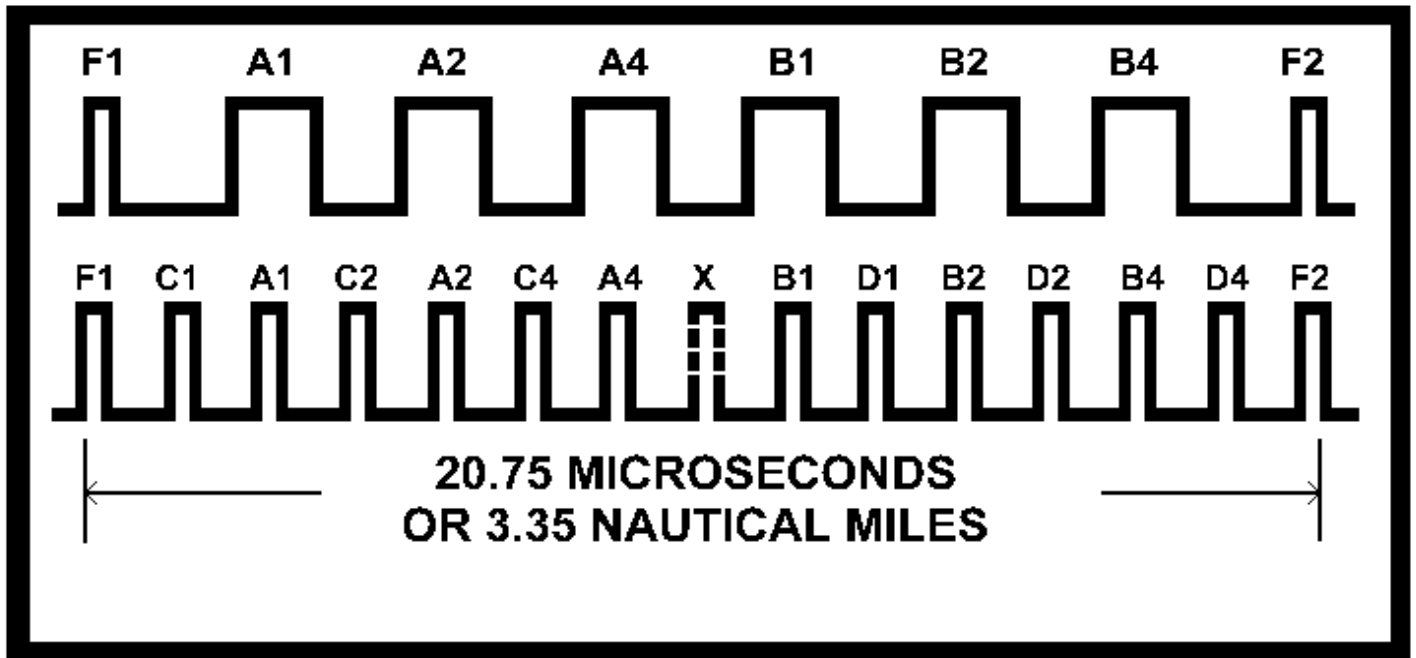
To find answers, perhaps we should begin with a little history. The Air Traffic Control Radar Beacon System (ATCRBS) is an outgrowth of the IFF equipment developed during World War II, at the same time radar itself was coming into use. The problem was differentiating between the good guys and the bad guys, and IFF (Identification, Friend or Foe) was the answer. The equipment on board each allied aircraft received the radar pulses, and transmitted a secret code in reply. There were 64 possible codes, and the idea worked quite well.

After the war the concept was adapted for air traffic control. Improvements were made, and the interrogator was separated from the radar itself. It still rotates around on the same dish, looking in the same direction, and is displayed on the same scope, in the same shade of green. (Ever wonder why the FAA never learned the advantages of color? I've wondered that too.)

The 64 codes consisted of two digits, called A and B. (These are not Mode A and B, that is something else altogether.) There were two knobs, A and B. Each digit has 8 possibilities, from 0 thru 7. $8 \times 8 = 64$, so there were 64 possible codes.

Figure 1 shows the original 64 code format, and today's 4096 code format under it. Each reply consisted of a framing pulse, some combination of the six possible data pulses, and another framing pulse. It all took place in 20.75 microseconds. At the speed of light, a radio signal travels 3.35 NM in that much time. Like ripples in a pond, the signal travels outward from the plane, and when the last of the signal leaves the antenna, the first is 3.35 milles away.

Figure 1



The pulse numbers are binary weighted, so it is easy to determine the relationship between pulses and the number they represent. The A digit, for example, looks like this, with 1 representing a pulse, and 0 representing no pulse:

	0	1	2	3	4	5	6	7
A1	0	1	0	1	0	1	0	1
A2	0	0	1	1	0	0	1	1
A4	0	0	0	0	1	1	1	1

The same pattern applies to digits (knobs) B, C, and D.

Pretty soon 64 squawk codes weren't enough, and a scheme evolved to place a pulse between each of the original pulses. This gave us $8 \times 8 \times 8 \times 8 = 4096$, the system we have today. The C digit nested into the A digit, likewise the D interdigitated with B. In the process the new X pulse appeared and could have been used to differentiate between Squawk and Altitude replies, but it wasn't. X has never been used for anything.

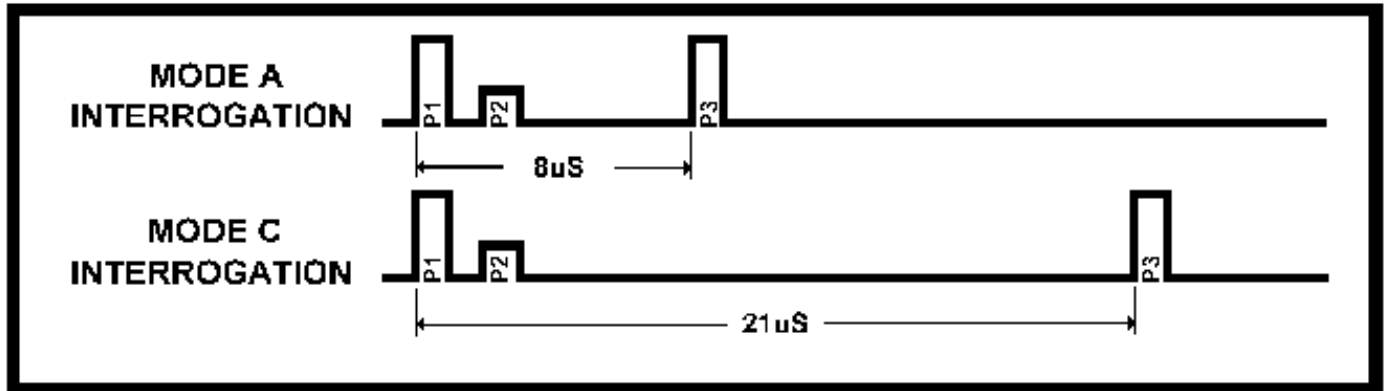
So today we have transponders with four knobs, which represent A, B, C, and D. Each can be set to anything from 0 to 7 (the switches don't have a position 8 or 9.) To squawk 1200, the A knob is set to 1, B is set to 2, C and D are set to 0.

If the transponder receives a Mode A interrogation, it transmits the squawk code, as set by the pilot. If it receives a Mode C interrogation, it transmits the altitude code, as supplied by the encoder. It's important to understand that AT NO TIME does the transponder send both. It's one or the other, if the ground station sends a Mode A interrogation, the transponder replies with a string of pulses that are the squawk code only. If a Mode C interrogation, the reply is altitude only.

Figure 2 illustrates the interrogation pulses. These pulses are transmitted on 1030 Mhz. All interrogators use the same frequency. The space between P1 and P3 defines the type of request, Mode A (the feds call this 3/A), or Mode C. If the P1-P3 timing is 8 microseconds, leading edge to leading edge, a Mode A response

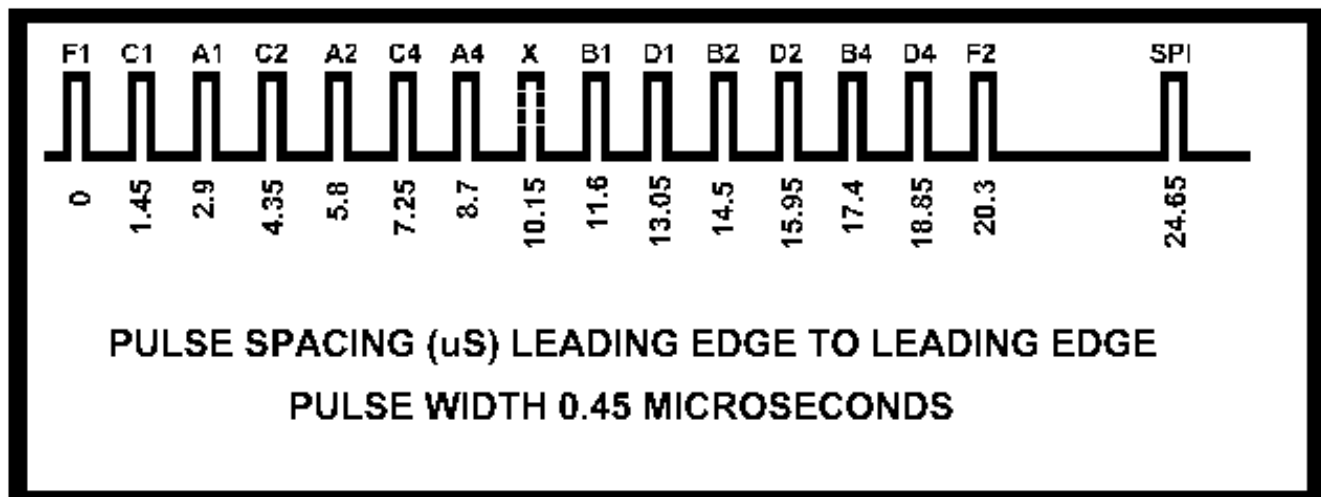
is expected, and if 21 microseconds, the request is for Mode C (altitude) data. P2 is used for sidelobe suppression, so that the transponder will only respond to the principal forward lobe of the rotating antenna, even when flying in strong signal near the interrogating site. Long range radar installations, the kind Center uses, typically alternate A, C, A, C, on a one to one ratio. ASR usually looks like this: A, A, C, A, A, C, with two squawk requests for each altitude interrogation.

Figure 2



The output of the transponder is on the frequency of 1090 Mhz. Pulse position and timing specs are shown in Figure 3. The SPI pulse is present only when the Ident button has been pressed, and lasts about 10 seconds.

Figure 3



There is no difference between a Mode A and Mode C reply. If a Mode A interrogation is issued, a Mode A reply is expected, and the pulses will be decoded that way. Likewise, if a Mode C request is made, the data received from the aircraft will be calculated as altitude. This works well with only one ground station, but with several stations interrogating the same aircraft, mistakes can and do occur.

The Mode C data is pressure altitude, i.e., set to 29.92". This is equally true whether you are using a blind encoder, or an encoding altimeter. (If it weren't so, the controller would have to know what type of encoder you are using.) Usually there will be a substantial difference between pressure altitude and the reading shown on the altimeter. Often hundreds of feet. (Hint: Turn your barometric adjust knob on your altimeter from one end to the other, and see how much difference it makes in the altitude reading. On most altimeters, it's about 2700 ft.)

The ground equipment automatically adds the necessary barometric correction, according to the local pressure. The controller sees the same reading on his scope that the pilot sees on the altimeter, if both are using the same barometric setting. It is possible, indeed likely, that another ATC facility is indicating this aircraft at a different altitude, since the barometric pressure varies from one location to another.

Each altitude code has an equivalent squawk code. The [list of altitude codes](#) shows how that same data would decode as a squawk rather than altitude. But each squawk code does not necessarily have an equivalent altitude. There are 4096 squawk codes but only 1280 altitude codes, one for each 100 foot increment from -1200 to 126,700 ft.

Why do the altitudes go all the way down to a negative 1200 ft? It's the barometric thing again. If you are physically located at sea level on a day with pressure above 29.92, your encoder will be putting out an altitude (pressure altitude) below zero. To accommodate the possible high pressures, the range goes down to -1200.

Altitude encoders switch from one code to the next nominally at the 50 foot point. Thus the code should indicate 1000 ft. at any height from 950 to 1050 ft., pressure altitude. But don't depend on it, the specifications are somewhat loose.

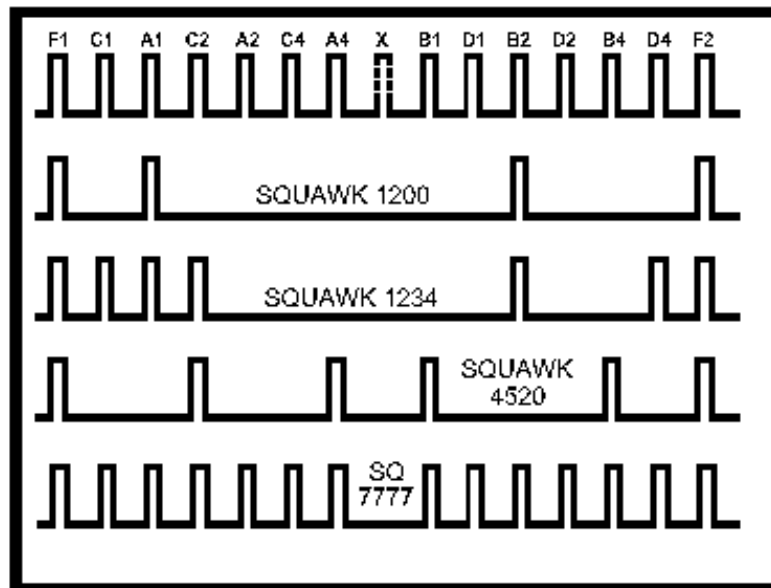
But in the real world, when does the encoder switch? This is a question of practical importance to the pilot, because it can make the difference between a violation or not. The answer isn't simple. Encoders switch when they feel like it. If the encoder was perfect (none are) and temperature and humidity and gravity and barometric pressure were standard (they never are) and there were no vibration or static system error (and if you believe in Santa Clause and the Easter Bunny), then the encoder will switch as stated above, at the 50 ft point. But consider just one variable, barometric pressure. If it was 29.93, just one one-hundredth of an inch above standard, the encoder would switch at the 40 ft point (1040, 1140, 1240 etc). At 29.96, the encoder would switch near the 10 ft point, and at 29.97 reported altitude would switch at the assigned altitude.

So you can see that if you are assigned 6000 ft, for example, your encoder would be jumping up and down between 5900 and 6000, while you are cruising steady at your assigned altitude. This is one reason why it's important to have a readout, so you can see what your equipment is reporting to ATC.

The altitude coding pattern was developed when mechanical encoders were the only way to digitize the data. It is somewhat bass-ackwards, with D2 as the most significant bit, followed with D4, A1, A2, A4, B1, B2, B4, in a gray code that changes every 500 feet. The least significant digit is C, with C1, C2, C4 following a recyclic code different from the gray pattern. Note that only one bit changes for each increment of altitude. Bit D1 is never used and always remains a "0". There are 3 illegal combinations of C bits, 000, 101, and 111.

One further note on the Mode C codes. Transponder data inputs are inverted logic. A logic "1" is ground, while a "0" is allowed to float to some positive voltage, depending on the particular transponder model. To indicate an altitude of 3500 ft., for instance a ground is placed on A4, B1, B4 and C2.

Figure 4



[Table of Mode A and Mode C Encoder Data](#)